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Fire Effects on Pacific Northwest Forest and Range Vegetation

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FIRE EFFECTS ON PACIFIC NORTHWEST FOREST AND RANGE VEGETATION

By

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I. INTRODUCTION

Our recognition of the role of fire in our Pacific Northwest ecosystems has come from studies of existing and past vegetation, fire scars on trees, soil charcoal layers, even-aged character of some of our forests, and recorded historical accounts. All of these are indicators that fire has been an important component in shaping our forests and grasslands over the centuries.

In any analysis of the effects of fire on forest and range ecosystems, vegetation becomes a very key factor since it is most immediately and directly affected by fire, provides the fuel for fire, determines conditions of fire hazard, and can vary considerably from place to place within an area. These influences, in turn, can directly or indirecty affect all the resources found within the ecosystem.

The objective of this publication is to provide a state-of-knowledge overview and discussion of the effects of both prescribed fire and wildfire on coniferous and non-forest flora of the Pacific Northwest. In the contents of this paper, the response of plants to burning is initially considered, followed by discussion of the reaction of the community as it aggregates the effects on its member species. The effects of fire on specific floristic ecosystems has been documented by several authors and will not be addressed within this paper although references are made to specific studies. Lastly, consideration is given herein to those subject areas where present fire-flora information for this Region is still lacking or incomplete.

II. HISTORICAL PERSPECTIVE

It is well documented that fire has been an important environmental factor in all floristic ecosystems of the Pacific Northwest. Newspaper accounts and excerpts from diaries and historical books indicate wildfire has prevailed on both sides of the Cascades in Washington and Oregon. Morris (1934), for example, documents a newspaper article in the Jacksonville Oregon Sentinel of August 8, 1868 "...it is very common for parties going into the mountains to set the whole country on fire. This we think very wrong. It not only kills the timber but also fills the valleys full of smoke, thereby rendering it very unhealthy. We have no doubt that many of the summer diseases are greatly aggravated by the smoky atmosphere."

A comment from the Ashland Tidings, a newpaper from southwest Oregon stated on Sept. 10, 1903 "the entire absence of smoke from the atmosphere this season is evidence of the good work of the Forest Reserve." The previous year (1902) happened to be one of the worst fire years documented since early settlers entered the Northwest (Morris, 1934). These comments imply that smoky airsheds were a common occurrence in the Northwest in the late 1800's.

An account given by Col. John C. Fremont (1854) in his diary for Dec. 8, 1843 as he passed through central Oregon stated: "..today we crossed the last branch of Fall River (the Deschutes River), our direction a little east of south, the trail leading constantly through pine forest. The soil was generally bare, consisting of a yellowish-white pumicestone, producing varieties of magnificent pines, but not a blade of grass; tonight our horses were obliged to do without food...." In 1826 Peter Skene Ogden described the same area as "wretched country" and "too miserably poor and destitute of resources" (Davies and Johnson 1961). Langille et al. (1903) documented the condition of xeric east-side ponderosa pine stands at the turn of the century: "In the yellow pine region bordering the timberless area of eastern Oregon the forest floor is often as clean as if it had been cleared, and one may ride or even drive without hindrance." Apparently, periodic wildfires were so common east of the Cascades that livestock forage was particularily scarce in those ecosystems not well represented by a herbaceous vegetation. After nearly 75 years of an effective fire control program much of the ground traversed by Ogden and Fremont is today choked by shrubs. Fire, as well as the absence of fire, has had a considerable effect on the vegetation of the area.

III. SOURCE AND FREQUENCY OF FIRE

Historically, as well as is true today, lightning has been a significant source of wildfire ignition. There is is also some evidence (Morris 1934) that Indians lit fires to control under-growth and assist in their hunting activities. By the last half of the 1800's early settlers populated the western valleys in significant enough numbers to perpetuate frequent burning during land clearing, grazing and logging activities. Newspaper accounts during the period indicate, in some cases, fires were set in the summer months as much for sport as for land clearing. Occasionally these fires escalated in size to burn thousands of acres. As a result, smoke often filled the atmosphere to such a degree that artificial lights were sometimes needed during mid day and ships could frequently not navigate inland on the Columbia or Willamette rivers.

Most of these wildfires occurred during periods of low relative humidity, low fuel moisture and sharp atmospheric pressure gradients creating high-velocity winds. As is true today, fire frequency, season of burn and intensity of burn were the three most important factors affecting the flora. The fire frequency and burn intensity varied widely across Pacific Northwest ecosystems depending upon prevailing climatic patterns, inherent fuel accumulation, and arrangement.

Fires on the west slope of the Cascades and the Coast Range were infrequent but very damaging when they did occur. Data (Martin et al. 1976) suggests fire frequency in Douglas-fir[1/] ecosystems varied from 50-400 years prior to organized fire control. Documentation indicates (Means 1980) many of these fires were not catastrophic but were underburns within a broad frequency of conflagration fires. There is some evidence (Hemstrom 1979) that the more mesic upslope communities dominated by Pacific silver fir, mountain hemlock, or lodgepole pine (Zeigler 1978) burned even less frequently. Stand structure within riparian areas suggests many of these mesic environments were burned by slow-spreading ground fires rather than high intensity conflagrations. In recent history, major fire years occurred west of the Cascades in 1849, 1857, 1868, 1883, 1902, 1910, 1927-29 and 1933 (Morris 1934). During these years, thousands of acres of timber land burned essentially out-of-control until some significant shift in weather conditions occurred.

Vegetation east of the Cascade Mountains developed under the influence of periodic light underburning. Documented fire frequencies range from 5 to 50 years with a 200 year interval being an exception (Martin, et al. 1976). Some variance in the periodicity occurred with geographic location. Fire frequencies appear lower in grass dominated understories than those supporting shrubs. For instance, frequencies in Blue Mountain forests of Oregon averaged 8 to 10 years (Hall 1976). Data from eastern Washington varies from 6 to 47 years (Wright, 1978) and southcentral Oregon 10 to 47 years (Weaver 1959; Volland 1974). Some variation also occurs according to the dominant vegetation. Fire appears more frequent in grass dominated understories at lower elevations than shrub and mixed conifer stands at high elevation (Arno 1976, 1980; Soeriaatmadja 1966; Wright 1978).

The non-forest vegetation in the Pacific Northwest has also experienced periodic burning. The length of interval between burns appear strongly correlated with rate of fuel accretion. Frequencies of 3-10 years are documented for natural grasslands (Vogl 1974), chaparral and mountain shrubland sites burned every 10-20 years (Vogl 1977) and sagebrush in frequencies of 30-70 years (Wright et al. 1979).

It is apparent that the present frequency of fire within forest and non-forest ecosystems is substantially lower today than it was in the last century. Preventing an environmental factor such as fire from operating, especially in ecosystems dependent upon that factor, will lead to significant changes in the vegetation. The response of vegetation to burning or protection follows certain principals. The attempt here is to review some effects of burning on the plant in a conceptual sense, then to aggregate these effects as plants are found in plant communities.

1/ Scientific names for plants are given in the Appendix.

IV. EFFECT OF FIRE ON THE PLANT

A plant's ability to withstand fire depends upon its heat tolerance and its fire resistance. Kayll (1968) defined heat tolerance as the ability of organs and tissues to withstand elevated temperatures. Both temperature and exposure time are important factors related to heat tolerance. He defined fire resistance as the ability to survive passage of a fire. Each species and growth stage has its own heat tolerance and fire resistance characteristics. Most of these values are unknown to us at this time. Documentation of burning conditions and flame characteristics, when compared to the plant response between species following fire, will give some indication of species susceptibility to heat and passage of a fire of given intensity. Such information documentation is an important part of prescribed burn evaluation, analysis, and prescription development for future burns.

Heat Tolerance

A plant's heat tolerance is dependent upon the kind of tissue being affected. Seeds are the most fire-tolerant stage in a plants life cycle. Jack pine seeds in cones have withstood 482°C (900°F) temperatures for 30 second exposure time (Kayll 1968). Douglas-fir seeds can survive 84°C (185°F) temperatures for 10 minutes. Grass seeds can tolerate 82° to 116°C (180° to 240° F) for five minutes (Sampson 1944). Tree stems probably have the next highest tolerance. They have been known to tolerate 57-59°C (137°F) for 30 minutes (Lorenz 1939). Bark growth characteristics vary between species, consequently sensitivity of tree stems to burning is considerably different dependent upon age and species. The approximated lethal temperature for leaf tissue is 60°C (140°F) for 1 minute (Byram 1948). Damage to leaves is related again to exposure time, current plant temperature and growth stage or moisture content. Wright (1970) showed moisture content alone will give considerable variance to exposure time if temperature is held constant. Actively growing seedling leaf tissue can be exposed to 50°C (120°F) temperatures anywhere from 1 minute to an hour depending upon the species (Kayll 1968; Martin et al. 1977).

Dormant leaf tissue can tolerate an additional 60° F more heat than actively growing tissue. This temperature varies considerably as to whether the solution within the tissue is frozen or in liquid phase. Roots are probably the most sensitive to heat. Studies with loblolly pine roots indicated they can experience 54°C (129°F) temperatures for at least 5 minutes (Kayll 1968). Most root hairs are located well within the soil profile. The damping effect of soil and moisture on burning temperature usually provides protection for roots.

It is of practical importance to know that the species targeted for consumption by fire will respond to the burning in certain ways depending upon the kind of tissue affected and position of growing points. For instance, growing points for conifer trees and shrubs are the root tips, terminal and lateral buds, and cambium layer. Growing points for grasses may be in the basal crowns or underground rhizomes and roots. Perennial forbs may have growing points above or below soil surface depending on the species. Lethal temperatures will vary, however, dependent on plant moisture content and arrangement of the fuel. Both of these factors are somewhat hidden in the term plant phenology or plant growth stage.

As a general rule burning when plants have higher moisture contents in either the live or dead plant material may result in cooler temperatures at the growing points. However, Wright (1970) found that moisture content actually increases the susceptibility of plants to heat. His data for squirreltail is shown in Figure 1. If moisture content is held constant, cooler temperatures require longer exposure times to achieve a lethal condition since temperature and exposure time are inversely related.

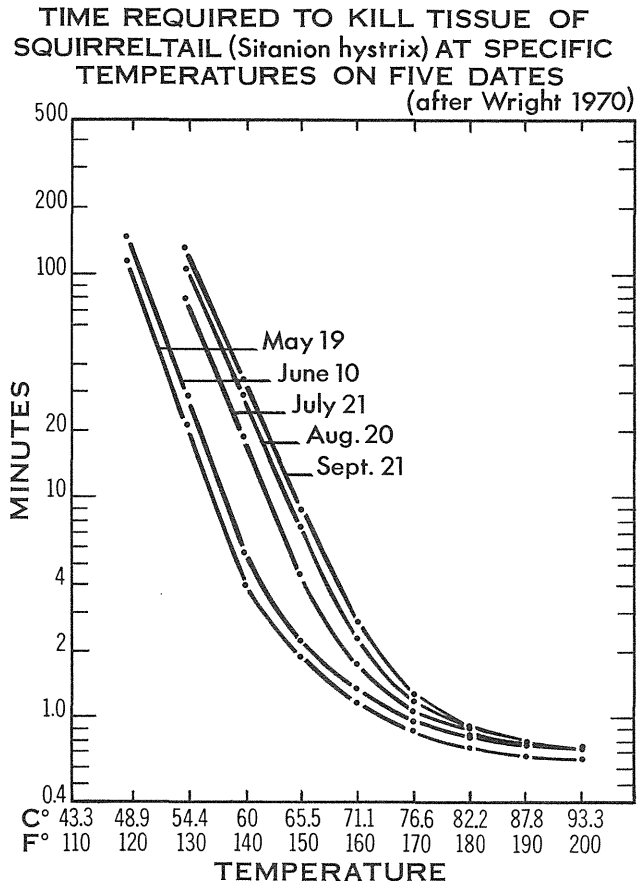

FIGURE 1.

The effect of fuel arrangement on fire behavior has been well documented especially for trees in stands. Fuel arrangement within a plant has a different connotation. In this case consideration is given to amount of fuel per unit basal area of the plant. The amount of fuel varies genetically between species, phenotypically depending upon the site potential of the land, and individual vigor of the plant as related to its history of use. For instance, both squirreltail and Thurber needlegrass are bunchgrasses. Genetically they are quite different in the amount of fuel per unit of basal area that is produced each season. Squirreltail has a low density of coarse fuel per unit of basal area while needlegrass produces a high density of fine fuel per unit of basal area. Given the same burning conditions squirreltail will burn with as high a temperature over a much shorter exposure time as Thurber needlegrass. Wright (1971) indicates there are seasonal differences between species in their tolerance to burning. Generally, squirreltail initiates growth earlier than needlegrass and appears more tolerant to midsummer burning than needlegrass. However, Wright found that abundant dead plant material in either species will result in damaging burns irrespective of season or species physiologic differences.

How much fuel is accumulated per unit basal area will also vary with the environment. Some sites produce more biomass per individual than other sites. Past grazing history, an other environmental factor, also affects plant vigor and density -and consequently the amount of fuel per unit of basal area available. A common complaint from managers is that a particular shrub-grass stand does not have enough fuel to carry a prescribed fire during the weather and fuel moisture conditions considered desirable for burning. In some instances, increases in fuel accumulation by changes in management, such as a change in the grazing program, may be feasible. In other cases, plant vigor and density may be so low that use of fire as a management tool may not be feasible.

Fire Resistance

The ability of a plant to survive the passage of a fire depends upon food reserve levels, mode of regeneration, and morphological characteristics inherent in the species.

Food Reserve Level

Carbohydrates (food reserves) are produced in the form of sugars and starchs as a result of photosynthesis. These food reserves are used as a source of energy for growth and reproduction in the plant and are stored during certain times of the year in the tops, crowns and roots. As a general trend food reserves in the roots are at their highest level early in spring before growth begins. These reserves decline rapidly and reach a minimum shortly after growth begins (Figure 2). Carbohydrates reach a maximum when the plant completes its annual life cycle. At this time some carbohydrates are translocated from tops to roots and crowns to be utilized in respiration during the dormant season. Generally plants are more susceptible to defoliation during flowering and seed formation, or period of most active growth, when carbohydrate reserves are low.

Most of the literature on carbohydrate reserves and plant vigor comes from grazing or clipping studies. These studies (McIlvanie 1942; McCarty and Price 1942; Wright 1967; Donart and Cook 1970; Trilica and Cook 1972; Trilica and Cook 1971; Perry and Chapman 1976) indicate that defoliation of the plant during its active growth period will reduce its top growth and increase its susceptibility to drought and cold injury. The effect of burning on plant carbohydrate cycles has not been studied. Consequently, any statements made are merely speculative.

The main difference between a burning and grazing treatment is that complete defoliation of the plant usually occurs with burning whereas some photosynthetic tissue remains from grazing, even under heavy utilization. The forage remaining after grazing is enough to support regrowth. Regrowth following burning comes solely from stored reserves since top growth is usually consumed. If a plant has received heavy grazing use annually so food reserves are at a low level, then defoliation by burning either within the same year or a following year may cause mortality of the plant. However, Uresk et al. (1976) indicate burning may have less impact on the plant than grazing if conducted during a plants dormant period. Burning, unlike grazing, is rarely an annual event within any plant community of the Pacific Northwest. Therefore, burning during the dormant period will rarely lead to plant mortality due to low carbohydrate reserves.

As can be expected, seasonal trends in carbohydrate reserves vary considerably between species so that burning at any particular season will be more detrimental for some species than others. For instance, squirreltail is a cool season grass in that it initiates growth early in spring, has a mid-summer dormancy period, and growth period in the autumn (Wright 1967). This species has as much carbohydrates in crowns as the roots (Coyne and Cook 1970). Squirreltail is less susceptible to mid-summer burning than in the spring or autumn. As a consequence, the species is usually very prominent following wildfires. Needle-and-thread is a warm season grass initiating growth in late spring and early summer without a pronounced dormant period in late summer (Wright 1967). Crowns are more important for food reserve storage than the roots (Coyne and Cook 1970). Needle-and-thread and Thurber needlegrass are much more susceptible to mid-summer burning than squirreltail and survive late spring and autumn burns more readily (Wright 1971; Wright and Klemmedson 1965). Figure 3 illustrates carbohydrate reserve curves for squirreltail and needle-and-thread.

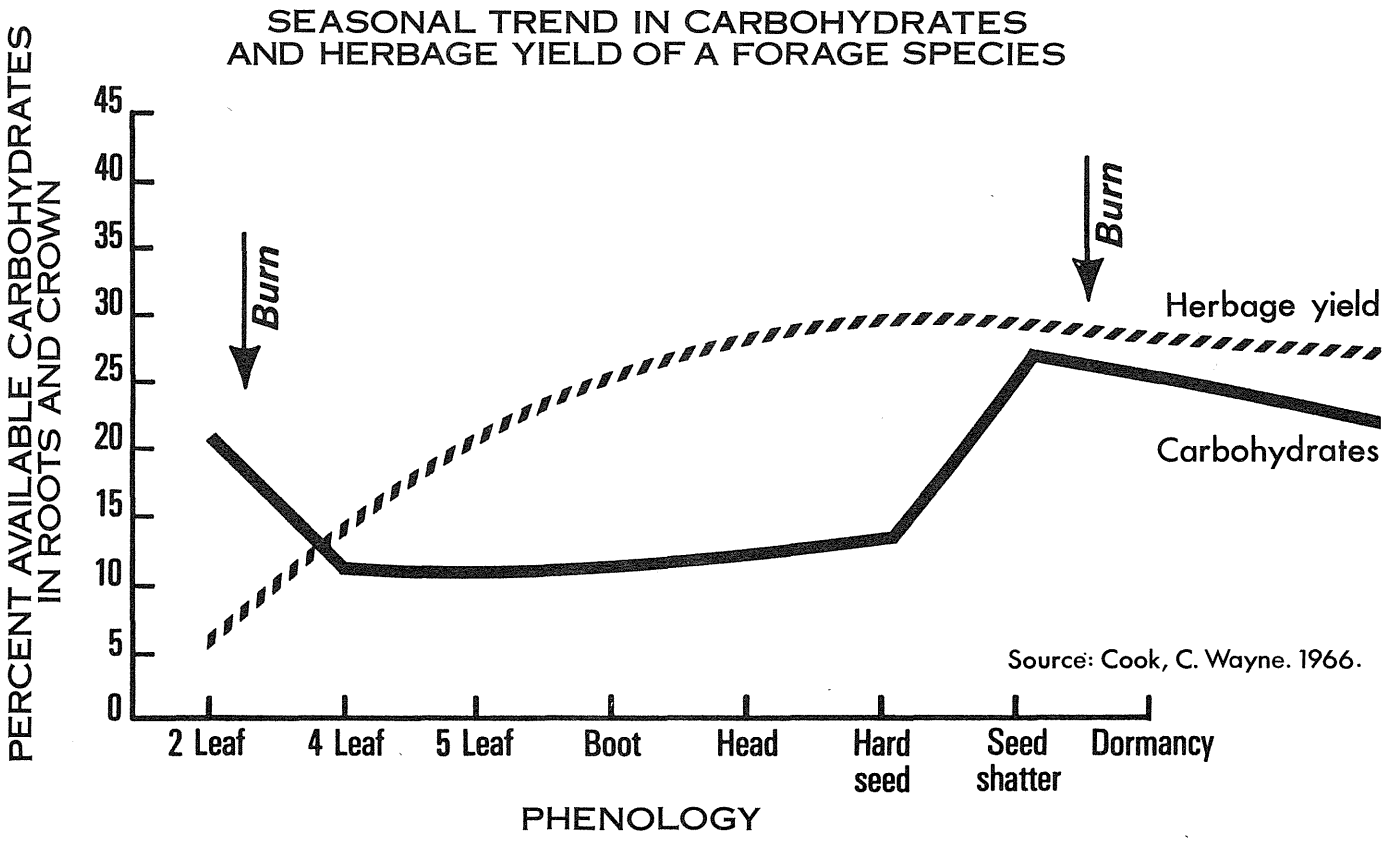

FIGURE 2.

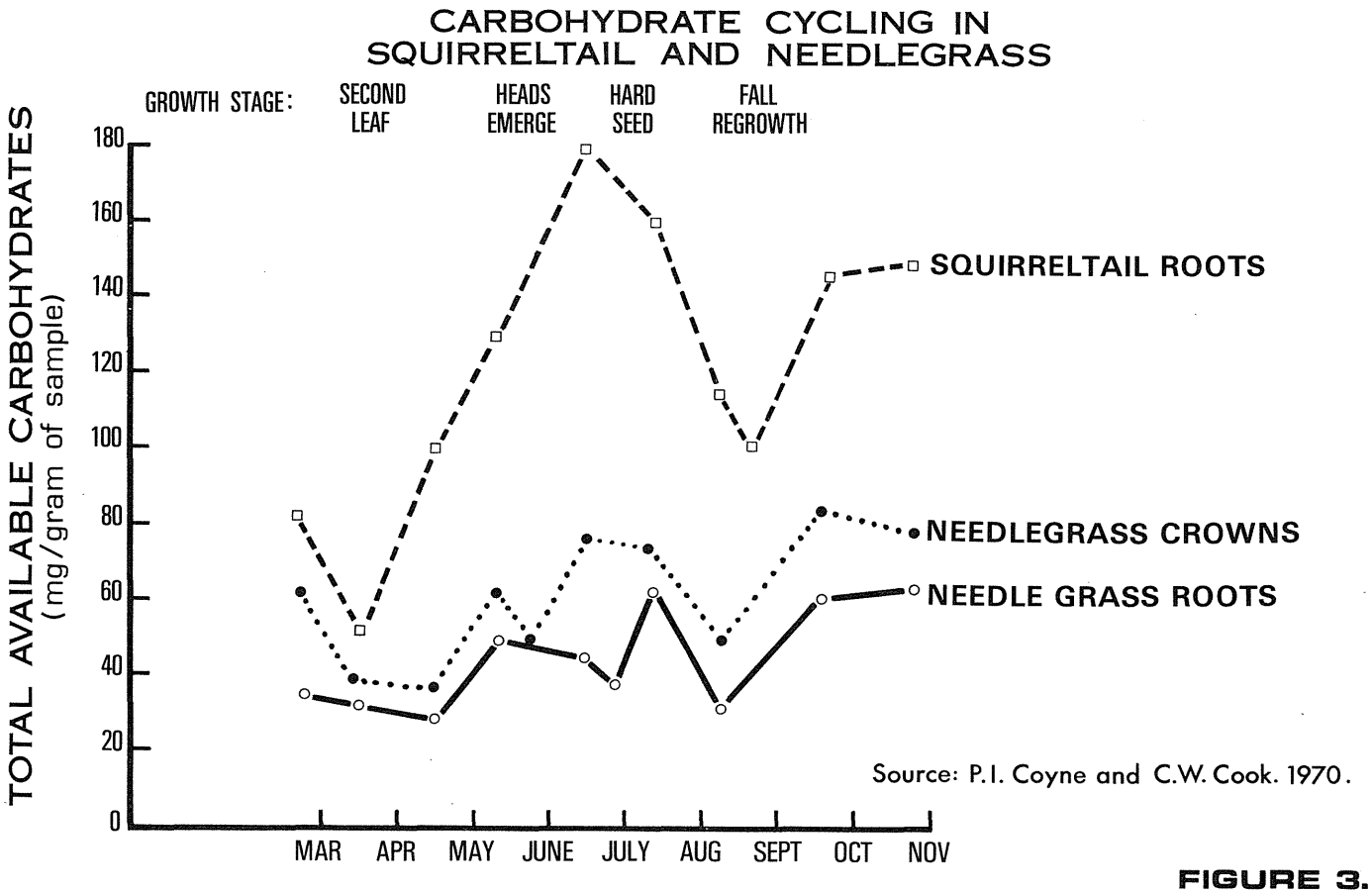

FIGURE 3.

Woody shrubs usually have higher food reserves in the roots than in the crowns (Coyne and Cook 1970). Seasonal trends in these reserves are different for species which flower in the spring than those which flower in mid and late summer. Bitterbrush is a spring flowering shrub so the carbohydrate reserves are lowest during leaf formation and flowering (McConnell and Garrison 1966). Burning stands of bitterbrush appears least detrimental to the plant during early spring or the winter dormant period. Several shrubs such as big sagebrush, rabbitbrush and goldenweed all flower in mid and late summer. Their carbohydrate reserve curve is lowest during leaf formation and the flowering period (Coyne and Cook 1970; Menkle and Trilica 1981). Burning in early to mid-summer is usually less detrimental for these shrubs than bitterbrush with the exception of big sagebrush which is very sensitive to burning (Wright et al 1979). A carbohydrate curve for bitterbrush and big sagebrush is given in Figure 4. Rabbitbrush and goldenweed are very resilient due to their resprouting tendencies, so mid-summer burns usually become occupied with these species at the expense of bitterbrush or serviceberry. Robertson and Cords (1957) report that some control of rabbitbrush has been achieved by mid-summer and early fall burning.

Mode of Reproduction

Mode of reproduction is the mechanism by which plant species are perpetuated from one generation to another. There are basically two modes of reproduction: vegetative and seed dependent. Each type of reproduction has its own principal for survival of the species and potential for regeneration.

There are four common types of vegetative reproduction: stem budding, deep underground stems, rhizomes, and root budding (after McLean 1969). Stem budding is characterized by shrub species as bitterbrush, chokecherry, serviceberry, rabbitbrush, horsebrush, snowbrush, vine maple, willow, Oregon grape and chinkapin. After passage of a fire, which may kill the aerial growth of a plant, adventitious buds form on the basal or lower portions of stems and develop into twigs and new photosynthetic tissue. For example, bitterbrush has a 3 inch stem section located 1.5 inches above and below the soil surface which may produce buds and twig sprouts (Blaisdell and Mueggler 1956). These authors found degree of sprouting was strongly related to burn intensity. The sprouting capability of bitterbrush apparently varies geographically across the western United States (Wright et al 1979). Reports on bitter-

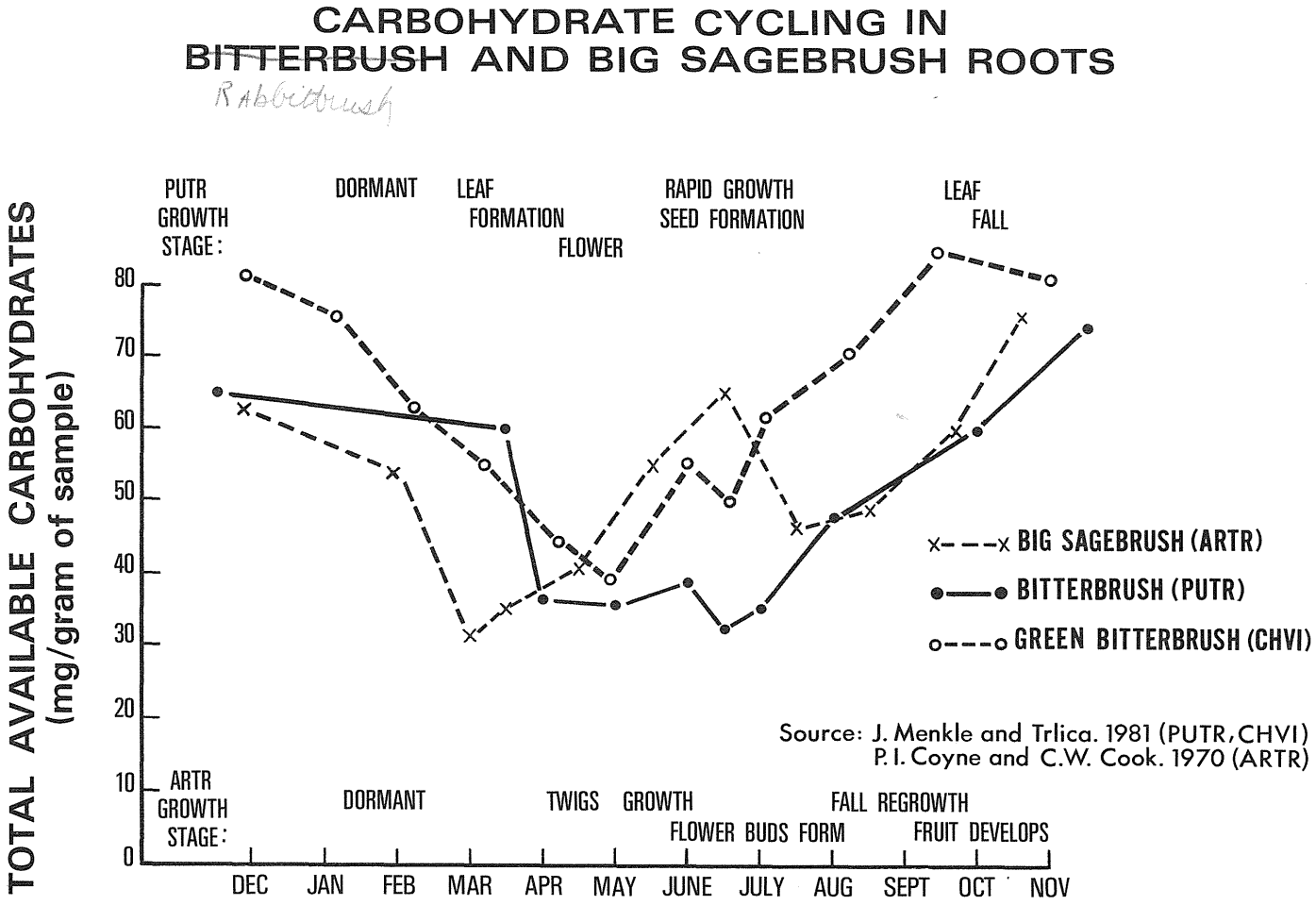

FIGURE 4.

brush sprouting vary within the Pacific Northwest from 80% of the original stems after spring burns in northeast Washington to 15-25% of the original stems in southcentral Oregon. Remeasurement of permanent plots in central Oregon [1/] indicates snowbrush and chinkapin can regain prefire canopy coverage and densities within five years following either early spring or autumn burning. This recovery potential is attributed to the sprouting ability of both species.

Deep underground stems are typified by bulbs and corms which persist in the soil after top kill by burning. Several perennial forbs from either the Liliaceae or Umbelliferae familes produce these bulbs: iris, segolily, wild carrot, licorce root, death camas, wild onions, and Indian potato.

Rhizomes are horizontally creeping underground stems which bud at nodes to form new rhizomes. Rhizome regeneration is quite common in the grasses and sedges. Kentucky bluegrass, pinegrass, elk sedge, and long-stolon sedge are examples. Shrubs such as snowberry, thimbleberry, and salmonberry, in addition to other members of Rosaceae family, have rhizomes. Brakenfern is an example of a fern with rhizomes.

Root budding is similar to rhizomes except buds develop along the primary roots from which aerial "suckers" develop. Red alder and trembling aspen are two species of trees which root bud.

In vegetative reproduction the growing points are usually located below the soil surface and are protected from intense heat. Regeneration potential for these species is to regain prefire size very rapidly with few new seedlings being established. One exception is root budding which considerably increases the post-fire stem density (Bartos 1979).

Seed-dependent regeneration is composed of four different types (after Lyon and Stickney 1974; Gill 1977) as follows:

1. On site prior to fire.
    a. derived from in-soil seed storage, fire stimulated germination.
    b. derived from on-plant seed storage, fire stimulated dispersal.
2. Off site prior to fire.
    a. derived from airborne dispersal.
    b. derived from animal borne dispersal.

Several shrub species produce seed which can be stored in the soil mantle for decades and require heat scarification to break dormancy and initiate germination. Snowbrush and green-leaf manzanita are examples of two species which can tolerate temperatures in excess of 200°F for 40 minutes and still germinate (Gratkowski 1962). Sweeney (1967) and Keely (1977) discuss variability in seed production and sprouting ability between Ceanothus and Arctostaphylos species in California. Redstem ceanothus demonstrates similar seed dormancy characteristics (Orme and Leege 1976). Snowbrush and greenleaf manzanita are sensitive to cold air temperatures and low light intensities associated with dense tree canopies. As a consequence, these species may be absent from forested stands in later stages of succession. Upon disturbance via logging or burning, surface soil temperatures rise considerably. Stored viable seed germinate to form the many brushfields or shrub-dominated understories evident on both sides of the Oregon Cascades.

The Legume family also produces seed which is stored in the soil over many years (Martin et al 1975). Wherever lupine species comprise the preburn plant community their density will increase substantially following burning although their composition will decline quickly within the first ten years.

The most common example of seed stored on the plant and dispersed by heat treatment is lodgepole pine which bears serotinous cones. These cones have tightly closed cone scales which open with heat exceeding 45°C (113°F) (Perry and Lotan 1979; Lotan 1976). Lodgepole pine is very sensitive to both low and high intensity fire. The bark is too thin to provide much insulation for actively growing cambium. The usual sequence is for the fire, whatever the intensity, to prepare an ash seedbed onto which the seed from serotinuous cones will fall, germinate and grow to replace the previous generation. Temperatures required to open serotinuous cones have also been experienced following logging activities in which cones from slash on the ground open and disperse their seed (Lotan 1964). Lodgepole pine varies in its ability to produce serotinous cones within the Pacific Northwest region. Lodgepole in eastern Washington and northeast Oregon express serotiny while those from central Oregon do not (Mowat 1960; Cochran 1973).

Other forms of seed regeneration are found in those plants which have either airborne or animal borne seed that may be dispersed onto a burned site from adjacent areas. The seeds of species such as fireweed, tansy ragwort, thistle, scoulers willow, and squirreltail are lightweight and either blow into the area or roll along the ground to eventually be lodged in a microsite within the burn. Other species such as chokecherry, chinkapin, bedstraw, buffalo bur, and stickseed produce heavy-edible or heavy-sticky seeds which cling to animal hair or are eaten by birds, bears, or rodents and are dropped as the animal traverses the burned area.

[1/] Data on file c/o L. A. Volland, Range Management, U.S. Forest Service, Regional Office, Box 3623, Portland, Oregon 97208.

The principal of survival for seed-dependent regeneration is that the seeds either require heat scarification to break dormancy, or escape the intense heat by their position relative to the fire. Seed viability for some species may be retained for decades. The parent plant usually has growing points at or above the soil surface and may be very susceptible to burning. Generally the season of burn, frequency of burn, and intensity of burn regulates seed survival. Temperatures greater than 120°C are usually considered lethal for many of these seeds (Keeley 1977).

Morphological Adaption

The last factor which may affect the survival of a plant to the passage of a fire is a morphological adaption. Cone serotiny in lodgepole pine could be considered as one adaptation (Perry and Lotan 1979), the other adaptations are the bark characteristics of the species (Hall 1976) and flammability of the foliage (Mutch 1970). Several tree species produce dead, insulating bark plates fairly early in the life of the plant.

Ponderosa pine, western larch, incense cedar, and Oregon white oak are some examples. The cambium layer rarely reaches a lethal temperature in these species given a light underburn. In the sapling stage they will usually withstand a low intensity burn quite favorably. Douglas fir, in the seedling and sapling stage, is quite susceptible to damage by even low-intensity ground fires. As it matures into the pole and small sawtimber size class it becomes fire resistant. In maturity it is quite fire resistant. By contrast several species such as grand fir, white fir, subalpine fir, engelmann spruce, lodgepole pine, aspen, and madrone have thin bark. A tree such as white fir may have photosynthetically active bark until the stem is 4 inches in diameter at the ground (Hall 1976). These latter species are usually killed by light underburning or sustain enough damage so the tree is weakened and dies from some other agent such as insects or disease.

V. EFFECT OF BURNING ON THE PLANT COMMUNITY

The community is a collection of plant species in competition with each other for the limited resources that are available. Each species has genetically controlled characteristics which adapts them to their environment. The plant community aggregates plant responses to burning and competition between species so that fire effects on the plant community become a manageable, predictable entity in time and space.

One important characteristic of the plant community that helps explain its response to burning is the vertical stratification that occurs within the community (Fig. 5). This stratification is represented by lifeform layers, each layer being composed of individuals of one lifeform i.e., trees, shrubs, or herbaceous vegetation. The lifeform layers are not of equal importance ecologically. The taller lifeforms, ones which control light or other environmental factors, are the most dominant. In forested communities the tree layer is the most dominant ecologically. In shrublands the shrubs hold this position. Removal of the dominant lifeform layer, either by burning, logging or grazing, will redistribute energy use and result in readjustments in the biotic and edaphic components. After fire has occurred on an area the rate of recovery is most rapid for the least dominant lifeform layer. For instance, the herbaceous layer usually responds quickly and stabilizes in density and species composition sooner than the shrub or tree layers.

The effect of burning on the community is expressed in at least four ways: stand composition, successional development, stand structure, biomass production and quality. Each community characteristic responds in a predictable manner based upon the effect of burning on individual plant species.

Stand Composition

Stand composition is the kind and amount of plant species which comprise the plant community. Burning affects stand composition by selecting against some species and stimulating others.

As a general rule the following trends can be observed:

1. Species with vegetative regeneration potential are favored over seed dependent species. Some seed dependent species may be temporarily eliminated or drastically reduced from the stand if an on-site seed source is not provided during burning. This can be accomplished by leaving untreated islands. Both big sagebrush and bitterbrush are easily killed by fire and may take 15-30 years to again regain a

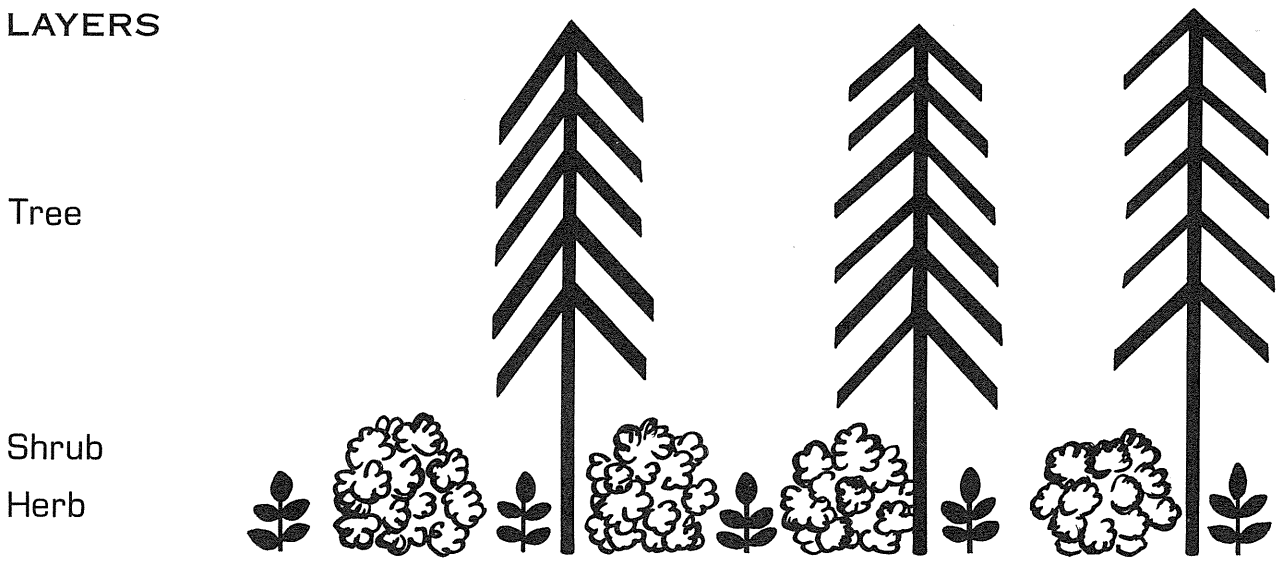

FIGURE 5.

dominant position in the shrub layer if undisturbed islands are not provided (Harniss and Murray 1973; Wright et al 1979). Snowbrush will immediately occupy a site by stem budding while greenleaf manzanita comes from heat scarified seed and requires a decade to regain its codominant position. In stands of the ponderosa pine/bitterbrush/long-stolon sedge community (Volland 1976) the rhizomatous long-stolon sedge will successfully retard the reestablishment of shrubs or trees for 15 to 25 years.

2. Species with morphological adaptations that either increase their resistance to burning or permit their establishment after burning are favored over those species without these characteristics. Ponderosa pine and western larch, both which have insulating bark characteristics, will tolerate light underburning in the seedling and sapling growth stages more readily than white fir, lodgepole pine or Douglas-fir (Weaver 1968). Oregon white oak stands, with the recent infusion of Douglas-fir in the Willamette Valley (Thilenius 1968) are an example of differential resistance to burning between species. Another example in the region is cone serotiny in lodgepole pine and its ability to completely occupy certain areas after wildfire.

3. Selectivity between species occurs due to seasonal susceptibility of plants with respect to the time of burning. Wright (1971) has indicated that midsummer burns are more detrimental to needle-and-thread, a warm season bunchgrass, than are burns in squirreltail, a cool season bunchgrass. Sandbergs bluegrass was not affected in another study (Wright and Klemmendson 1965) and increased in another until the 12th year (Daubenmire 1975).

Bailey and Anderson (1980) have shown fires in shrublands are considerably hotter than grassland burns. The preburn species composition will have considerable effect on burn intensity and post burn response. Season of burn and burn intensity are given as selective factors affecting the response of bluebunch wheatgrass compared to Idaho fescue (Conrad and Poulton 1966). Controlled burning in different seasons has been reported as either detrimental or beneficial to bluebunch wheatgrass (Anderson and Bailey 1980; Willms et al 1980a,b). A mid-summer wildfire in a sagebrush/wheatgrass community appeared less detrimental to bluebunch wheatgrass than either Cusick bluegrass or Thurber needlegrass (Uresk et al 1980). Each species responded slightly differently to the burning depending upon the plant characteristic being measured.

The results of an August experimental burn in a sagebrush/wheatgrass-fescue community is documented by Mueggler and Blaisdell (1958). Their results are given as change in herbage production. Burning increased the production of Columbia needlegrass, prairie junegrass, western yarrow, and corymbose pussytoes while significantly decreasing bluebunch wheatgrass, Idaho fescue, and needle-and-thread grass. Bitterbrush and big sagebrush strongly declined following burning. Downy rabbitbrush and horsebrush readily sprouted and showed increases after burning. The lupines, which have high inter-seasonal storage of viable seeds, expressed some of the greatest post-burn production increases.

Much of the earlier documentation on fire as it affects stand composition has been the result of mid-summer burning - mostly wildfire. In most instances burning conditions and flame characteristics were not recorded or reported. One should probably assume an average worst dry season burning situation for these studies. Different vegetative results can be expected as season-of-burn varies from mid-summer. It is important to remember that very little research is available for effects of winter, spring, or autumn burns, although current guidelines for prescribed burn evaluation are providing new and useful information on recent burning. Published documentation of burning conditions, fire behavior, and vegetative response is important to the assessment of fire effects across several ecosystems.

Stand Succession

Stand succession reflects the change in species composition, abundance and biomass of a plant community in time. The stage of succession and rate of change between stages are both considered under stand succession. Fire frequency, a time related function, affects successional change. In general, seral species, those dominants in early succession stages, are more adapted to periodic burning than species found in an infrequent-fire environment. The seral species usually have fire resistant bark or some reproduction characteristic which increases their chances of survival to another generation. Mutch (1970) has suggested some seral species may have physiological characteristics which are conducive to periodic burning in ecosystems dominated by them. The following successional trends occur within a plant community as a result of burning:

1. Burning may prevent a lifeform layer from developing into an ecologically dominant position within the stand. In both forest and non-forest communities the post burn recovery rate of the herbaceous layer is greater than the shrub layer. The tree layer is the last to stabilize in density and species composition. The frequency of burning, therefore, shapes the relative dominance of lifeform layers that comprise a community. For instance, non-forest shrub stands can be reverted to grasslands with frequencies less than 20 years (Wright et al 1979).

   Forest stands in which fire consumes the tree overstory layer revert to the next most ecologically dominant layer. In the western Cascades the next most ecologically dominant layer is composed of shrubs. The brushfields of snowbrush-manzanita, big huckleberry, (Minore et al 1979) and rhododendron are evidence of past wildfires. East of the Cascades the next most ecologically dominant layer beneath the tree overstory may either be shrubs or herbaceous vegetation depending upon site potential. Again, brushfields of snowbrush/manzanita, deerbrush-maple, and ninebark serve as examples. Under more xeric conditions high-intensity fires may result in stands of bluebunch wheatgrass or Idaho fescue, cheatgrass, or long-stolon sedge. When forest stands are underburned without appreciable mortality to tree overstory, burn intensity will determine which understory life forms are most impacted and how fast the various layers will respond. Underburned stands usually develop successionally at a greater rate than when the dominant tree layer is removed.

   The herbaceous layer may become prevalent over shrubs if regeneration characteristics of the perennial forbs and grasses favor rapid reestablishment. Since recovery rate varies between lifeforms, burning usually favors herbaceous growth over woody plants for several years. Land managers can manipulate the relative dominance between layers by effectively combining proper burning technique with burning conditions. With higher intensity prescribed fires or wildfire the opportunities for manipulation are usually not favorable.

2. Burning often favors annual species over native perennials thereby holding the community in an earlier successional stage. The seeds of annuals seldom are destroyed by the heat of low-intensity burns or incomplete litter consumption in hotter burns. At the same time, the environment is improved for germination and seedling establishment. Therefore, burning is usually not completely detrimental to annual plants. In the case of cheatgrass, early summer burns tend to suppress its density more than mid-summer and autumn burns (Wright et al 1979). Young et al (1976) found the amount of unconsumed litter layer was positively correlated with post-burn cheatgrass populations. Some annual forbs produce a chemical which inhibits either germination or growth of other species. Tarweed is one example. Plant succession to latter stages of community development becomes hindered, depending on how burning impacts these annual species.

3. The plant community progresses towards a new equilibrium with its environment when protected from fire. In forest and shrublands ecological dominance usually changes toward either more shade tolerant, more mesic, or less fire resistant species (West 1969).

   Succession is considered unidirectional in these types of stands. This kind of successional development is not without its costs. Hall (1977) ascribes the loss of herbaceous production in the Blue Mountains of Oregon to tree canopy closure from expansion of Douglas-fir and grand fir under a predominately pine overstory. Fire protection in grassland communities leads to cyclic succession patterns (Vogl 1974; Daubenmire 1968). Temporary increases in the number of species may occur, especially forbs. However, the number of individuals per species will vary with the reproductive characteristics of each species, chemical inhibition between species, and the number of recently disturbed animal burrows. Periodic burning may reduce the number of individuals per species but not necessarily the number of species per area.

Stand Structure

Stand structure is the density, size or age class distribution of species in space. Fire intensity, a space related function, affects stand structure. Stand structure is an important component of habitat diversity.[1/] The importance of habitat diversity to wildlife species has been recently reviewed by Thomas (1979). Koehler and Hornocker (1977) discuss the effect of burning on pine marten habitat. These authors found fire an important agent in establishing and maintaining habitat diversity in high elevation forest types. The place of habitat diversity and stand structure in the functioning of west-side Douglas-fir ecosystems is presented by Franklin et al (1981). Similar concepts are applicable to east-side ecosystems but have not been investigated on such an integrated basis as the previous study.

Stands dominated by monospecific lifeform layers usually respond differently than those containing more than one species. Layers dominated by a single species usually occur on the more severe environments such as imperfectly drained soils, very cold topographic positions, nutritionally impoverished or extremely xeric sites. In these situations fire does not convert the stand to other species but, depending upon the fire intensity, will create nonrandom pattern in the existing stand composition by differences in sizes and density. When layers in stands are comprised of more than one species then habitat diversity increases by having both structural and successional factors operating simultaneously in space and time.

1/ Habitat diversity: the relative degree of abundance of habitats or habitat features per unit of area (Thomas, 1979).

Light underburns have variable fire intensity in space and result in a mosaic of stands having different composition and structure. High intensity wildfires lead to a more homogeneous stand structure so that placing these units in space becomes more critical. The use of broadcast burning for fuel reduction and site preparation in westside clearcut logged units will develop fairly uniform stand structure within the unit. Habitat diversity is then regulated by dispersion of these units in space and over time. Another example of development of stand structure is lodgepole regeneration which occurs after high intensity wildfire and produces fairly large, even-sized stands. In some instances stand structure is manipulated by removing the more susceptible size classes with underburning. This usually alters the recovery rate of a particular lifeform layer. This technique is applied to the tree layer during silvicultural treatment as a means of regulating stand stocking level. Similar results could be acheived in the shrub layer of some plant communities.

Biomass Production and Quality

Biomass production is the amount of material grown by the stand over time. Generally removing a lifeform layer by burning will increase production of the remaining layers. Lifeform layers immediately subordinate to those affected will respond more vigorously. For instance, removal of a shrub component under a tree layer left fairly intact will substantially increase the production of the herbaceous layer, more so than the tree layer. Even though the production of one layer may increase, that increase may not offset the production lost in removal of the other layer.

The effects of burning on biomass production in nonforest communities is documented in several reviews (Daubenmire 1968; Vogl 1974; Wright et al 1979). Removal of the shrub layer may triple production of the herbaceous layer although any phenomenal increase is usually short lived. One study (Mueggler and Blaisdell 1958) indicated a decline for two years after mid-August burning. Season of burn has been reported to affect stem elongation in bluebunch wheatgrass (Willms et al 1980 b&c). Grassland production may be just as variable as a result of burning. In many instances competition within a single life layer may be more intense than between layers. Interspecific competition, release of chemical substances in litter, and effect of post-burn litter accumulation, are mentioned as some reasons for declining production following burning.

In eastside forest communities underburning within ponderosa pine stands has temporarily increased production of the herbaceous layer (Hall 1976; Weaver 1967; Wright 1978). The shrub layer is usually set back temporarily depending upon fire intensity and regeneration characteristics of the species. Similar results have been documented for aspen communities in Wyoming (Bartos 1979) and an aspen-grassland complex in Alberta (Anderson and Bailey 1980).

Biomass quality is the nutrient content of the forage and its digestibility for the grazing animal. The general trend is for biomass quality to increase temporarily after burning (Daubenmire 1968; Vogl 1974). Often changes in plant color and vigor the first growing season or two following burning is indicative that quality has improved. Some improvement may be due to release of certain nutrients by burning (Boyer and Dell 1980; Clayton 1976; DeByle 1976) although intensity of burn greatly affects the availability of these nutrients (Landsberg and Cochran 1980; Stark and Steele 1977; Stark 1977, 1980). Temporary increases in available water from changes in stand composition and structure after burning will improve quality.

Grazing animal preference for post fire vegetation has been noted (Willms et al 1980a; Vogl 1974). In some instances, livestock utilize the forage from beneath pole-size thickets and dense tree overstories that normally would not be grazed before burning. As a result, forage availability and livestock distribution is improved over pre-burn conditions. A word of caution is in order. Permitting grazing of first year plants, especially those resulting from early spring or summer burns, may reduce the vigor of such vegetation since utilization would occur twice in one season, once by burning, and once by grazing. Close coordination between grazing and burning plans is necessary to successfully acheive multiple resource management goals.

VI. SUMMARY

Historically, fire has been a part of Pacific Northwest ecosystems. Modern man's intervention through the exclusion of fire has apparently created as many problems as it attempted to solve. Increased fire prevention and suppression emphasis has resulted in a 70-80 year flammable fuel accumulation. In many situations, loss of resource production has also occurred. Timber stands on many sites have become either overstocked or stagnated due to the removal of fire as a natural thinning agent. Forage production in both shrublands and forested rangelands has declined from tree canopy closure and expansion of shrubs.

As land managers we are still a long ways from a solid understanding of the effects of either wildfire or prescribed fire on forest and range vegetation. The need for better documentation of burning conditions, fire behavior, and pre and post vegetation changes is necessary to better adjust these general concepts to local experience. At this time we can generally say fire frequency regulates successional development of the plant community, while fire intensity regulates stand composition and stand structure.

Fire is a management tool we as professionals should not do without. However, wise use of that tool is imperative in an age and culture characterized by so many environmental concerns. Professional evaluation of the effects of fire on those resources for which we are held accountable is an important part of that wise use.

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APPENDIX A

EFFECTS OF FIRE ON SOME PACIFIC NORTHWEST VEGETATIVE TYPES

GRASS AND GRASSLIKE SPECIES

Species	Prefire regeneration mode	Mode, Post-fire regeneration response 1/	Degree of fire resistance 2/	Comment	References
Bluebunch Wheatgrass	warm season bunchgrass. Seed dependent	seed germination or weakly rhizomatous, moderate to rapid	moderate	Response variable with season of burn, intensity and past graze mgt.	Wilms et al. 1980b; Uresk et al. 1976 Wright et al. 1979
Bottlebrush Squirreltail	cool season bunchgrass. Wind dispersed seed	seed germination, residual plant survival, rapid	resistant	More resistant to mid-summer than spring burning.	Wright 1971
Cheatgrass	annual, heavy seed, prolific seeder	seed germination, very rapid	very resistant	Very hot burn with litter consumption reduces post burn density.	Daubenmire 1968 Young et al. 1976
Crested wheatgrass	warm season bunch grass, seed dependent	moderate to slow	susceptible to moderate	Response variable with season of burn intensity & past graze mgt.	Anderson & Bailey 1979 Wright et al. 1979
Idaho fescue	cool season bunchgrass, heavy seed	seed germination, residual plant survival, moderate to slow	susceptible to moderate	Resistance variable due to season of burn, plant moisture and fire intensity.	Conrad & Poulton 1966 Wright et al. 1979
Kentucky bluegrass	cool season, rhizomatous	rhizome elongation, rapid	resistant	Most damage from hot, spring burning.	Daubenmire 1968
Mat Muhly	warm season, seed rhizome	moderate	resistant		Anderson & Bailey 1980
Needle and Thread	warm season bunchgrass, heavy seed	moderate to rapid	susceptible	Autumn burns least detrimental, prevent high fuel loads prior to burn.	Wright 1971
Pinegrass	rhizome, seed	very rapid	resistant to moderate	Palatability improved by burning.	McLean 1969 Tiedemann & Klock 1976
Prairie junegrass	cool season bunchgrass, heavy seed	residual plant survival, rapid to moderate	susceptible to moderate		Wright et al. 1979
Sandberg bluegrass	cool season bunchgrass, heavy seed	residual plant survival, rapid	moderate to resistant		Wright et al. 1979
Slender wheatgrass	warm season bunchgrass, heavy seed	slow	very susceptible	Most susceptible to early spring & late August burn.	Bartos 1979
Thurber needlegrass	warm season bunchgrass, heavy seed	slow	susceptible	Autumn burns least detrimental, prevent high fuel loads prior to burn.	Uresk et al. 1976
Timber oatgrass	warm season, seed	moderate	moderate	Increased from mid-summer burning.	Minore et al. 1979
Elk sedge	rhizomes, heavy seed	rhizome extension, very rapid	resistant	Developed under light underburning.	Hall 1976
Long-stolon sedge	deep rhizomes, heavy seed	rhizome extension, very rapid	resistant	Very resistant to hot, mid-summer burns - excellent competitor.	Volland 1976
Ross sedge	shallow rhizomes, heavy seed	rhizome extension, rapid to moderate	resistant	Not as aggressive as elk sedge or long-stolon sedge.	Tiedemann & Klock 1976

1/ Post-fire Regeneration Response (Based on number of years to approximate preburn frequency or coverage):

Slow	>10 years	Rapid	2-5 years
Moderate	5-10 years	Very rapid	1-2 years

2/ Degree of Fire Resistance (Probability that at least 50 percent of species population will survive or reestablish after passage of a fire):

Resistant	>65 percent chance	Susceptible	10-34 percent chance
Moderate	35-64 percent chance	Very susceptible	<10 percent chance

APPENDIX A (continued)

HERBS

Herbs Species	Prefire regeneration mode	Mode, Post-fire regeneration response 1/	Degree of fire resistance 2/	Comment	References
Balsam root	windborne seed, thick caudex	caudex regrowth, rapid	resistant		Wright et al. 1979
Beargrass	corm	corm budding, moderate	moderate	Resistant to light burns.	Stickney 1980
Bedstraw	sticky seed, animal dispersed	seed germination, moderate	moderate	Resistant to light underburns.	Anderson & Bailey 1980 Anderson & Bailey 1979
Bracken fern	deep rhizomes	rhizome expansion, very rapid	very resistant	Not reported to be affected by burning.	Lyon & Stickney 1976 Tiedemann & Klock 1974
Broadleaf arnica	shallow rhizomes, windborne seed	rhizome expandion, rapid	resistant		Lyon & Stickney 1976
Buckwheat	winged, light seed	seed germination, slow	very susceptible		Wright et al. 1979
Death camas	deep underground corm	corm regrowth, rapid	resistant		Wright et al. 1979
Fireweed	wind dispersed seed, moderate deep rhizome	rhizome and seed, very rapid	resistant		Tiedemann & Klock 1976 Lyon & Stickney 1976 Bartos 1979
Heartleaf arnica	wind dispersed seed shallow rhizomes	rhizome elongation, rapid to moderate	moderate to susceptible	Resistant to spring and light underburns.	Hall 1976 McLean 1969
Indian paintbrush	deep taproot	caudex regrowth, moderate	moderate		McLean 1969
Lambstongue	windborne seed	seed germination, rapid to moderate	resistant		Wright et al. 1979
Lupine	heavy seed, deep taproot	candex regrowth, heat scarified seed, rapid	resistant		Lyon & Stickney 1976 McLean 1969
Pearly everlasting	seed dependent, airborne	seed germination, moderate	resistant		Minore et al. 1979
Sheep sorrel	seed dependent, airborne	seed germination, moderate	resistant		Minore et al. 1979
Sidebells pyrola	heavy seed, shallow roots	seed germination, slow	susceptible		McLean 1969
Strawberry	shallow roots, stolons	stolon budding, rapid to moderate	moderate to susceptible	Resistant to light burns.	Hall 1976 McLean 1969
Twinflower	shallow roots, stolons	stolon budding, moderate	susceptible		McLean 1969
Western yarrow	seed dependent, airborne	seed germination, moderate	resistant to moderate		Wright et al. 1979 Anderson & Bailey 1980

APPENDIX A (continued)

SHRUB SPECIES

Species	Prefire regeneration mode	Mode, Post-fire regeneration response 1/	Degree of fire resistance 2/	Comment	References
Antelope bitterbrush	heavy seed, animal dispersed	Basal stem sprouts, seed germination, rapid to slow	Very susceptible to moderate	Variable results with post-burn sproating based on season of burn, plant vigor and soil moisture situation.	Wright 1972 Blaisdell & Mueggler 1956
Bearberry	fleshy seeds shallow roots	stem budding moderate	moderate to susceptible	Most resistant to light burns.	McLean 1969 Stark-Steele 1977
Big huckleberry	Rhizomes, seed	vigorous sprouter, rapid to moderate	resistant	Difficult to underburn without pretreatment	Minore et al. 1979 1976
Big sagebrush	Windborne seed	seed germination, slow	very susceptible	Burning commonly used to control species	Wright et al. 1979
Bitter & Chokecherry	heavy seed, animal dispersed	stem budding, rapid to moderate	resistant	Establishes on hot, midsummer burns	Anderson & Bailey 1980
Common snowberrry	Rhizomes, seed	Vigorous sprouter, rapid to	resistant		McLean 1969
Curleaf mountain mahogany	heavy, wind dispersed seed	seed germination, slow	very susceptible	Underburn when shrub moisture high but understory grasses cured.	Wright et al. 1979
Currant	heavy fleshy seed, animal dispersed	seed scarified, basal stem sprout, rapid	moderate	Common pioneer on hot burns xeric sites	Wright 1972
Deerbrush	heavy seed	seed heat scarified, stem sprouts, rapid	resistant		Kilmore 1973
Elderberry	heavy fleshy fruit animal dispersed	basal stem sprouts, moderate	moderate		Wright 1972
Golden chinkapin	Sticky, heavy seed animal dispersed	stem sprouts, rapid	resistant	Aggressive increaser after burning	Volland 1976
Greenleaf manzanita	Fleshy heavy seed animal dispersed	Heat scarified seed, moderate	resistant	Occupies site within 10 years of burn.	Volland 1976 Wright 1978
Green and Gray Rabbitbrush	airborne seed	Stem sprouting, rapid	moderate to resistant	Complete mortality by burnin rarely documented	Wright 1972
Grouse huckleberry	fleshy seeds, shallow roots and stolons	stem budding, moderate	moderate		McLean 1969
Horsebrush	windborne seed	Basal stem sprouts, rapid	resistant		Wright 1972
Mallow ninebark		Basal stem sprouts, moderate	moderate		Wright 1972
Ocean spray	windborne seed	Basal stem sprouts, moderate	moderate		Wright 1972

APPENDIX A (continued)

SHRUB SPECIES

Species	Prefire regeneration mode	Mode, Post-fire regeneration response 1/	Degree of fire resistance 2/	Comment	References
Oregon boxwood	deep taproot	stem bud, moderate	susceptible to moderate		Wright 1971 McLean 1969
Oregon grape	Shallow rhizomes	Rhizome buds, moderate	moderate to very susceptible	Damage from burning varies considerably with reported study.	Wright 1972 McLean 1969
Princespine	heavy seed, moderate deep root and rhizomes	rhizome buds, slow	susceptible	Intensity of burn appears unimportant.	Stark-Steele 1977 McLean 1969
Rabbitbrush goldenweed	light, airborne seed	stem sprouts rapid	resistant	Common pioneer in conflagration burns.	Volland 1976
Redstem ceanothus	heavy seed	Basal stem sprouts, heat scarified seed, rapid	resistant	Establishes on hot, mid-summer burns.	Wright 1972
Rose	heavy fleshy fruit, animal dispersed	basal stem sprouts, moderate	moderate		Wright 1972
Salmonberry	fleshly seed animal dispersed	rhizome buds, rapid	resistant		
Scouler willow	airborne seed	stem sprouting, rapid	resistant		Lyon & Stickney 1976
Serviceberry	heavy, fleshy seed animal dispersed	basal stem sprouting, moderate	moderate	Damage from burning varies with intensity and season of burn	Wright 1972 Lyon & Stickney 1976
Snowbrush	heavy seed	stem buds, heat scarified seed, rapid	very resistant	Common pioneer in conflagration burns. Occupies within 5 years.	Tiedemann & Klock 1976
Spirea	light weight seed	rhizome and basal stem sproats, moderate	moderate		Lyon & Stickney 1976 Wright 1972 Tiedemann & Klock 1976 Wright 1978
Vine maple	heavy, winged seed	stem buds, rapid	moderate		
Western thimble-berry	rhizomes, fleshy seeds	rhizomes, rapid	resistant		Lyon & Stickney 1976

APPENDIX A (continued)

TREES

Species	General Response to Fire	Comments	References
Douglas-fir	Old trees fairly resistant to fire	Young trees susceptible to through scorching of crown or girdling of tree; fire can be used to control species	Franklin et al 1981;
Engelmann spruce	Susceptible to all but light fires	Fire can be used in control-species	
Incense-cedar	Old trees resistant to fire	Young trees readily killed & species controlled by fire	
Lodgepole pine	Killed or injured by all but light surface fires	Seeds prolifically after fire, even where not serotinous	Perry and Lotan 1979; Cochran 1973; Lotan 1976
Ponderosa pine	Probably most resistant to fire of any western tree	Often killed by crown damage from intense fires	Weaver 1968; Hall 1977; Wright 1978; Soeriaatmadja 1966
Quaking aspen	Top readily killed by all but light surface fire	The species root-suckers profusely after fire	Bartos 1979; Bailey and Anderson 1980
Sugar pine	Old trees resistant to fire	Young trees susceptible to fire.	Kilgore 1973
True firs	Killed or injured by all but light fires	Species generally reduced by fire	Kilgore 1973; West 1969
Western hemlock	Old trees somewhat resistant to fire where extensive root damage not caused by complete duff consumption	Species generally reduced by fire	Franklin et al 1981
Western juniper	Old trees somewhat resistant to all but intense fire	Fire can be used to control increase in juniper	Wright et al 1979;
Western larch	Some consider it the most resistant Northwest tree; seedlings more susceptible than ponderosa pine seedlings	Able to refoliate after scorching of crown	Debyle 1976; Stark 1977 Stickney 1980
Western white pine	Killed or injured by all but light fires	Species generally reduced by fire	Kayll 1968

APPENDIX B

Plant List

Common Name	Scientific Name
TREES	
Douglas-fir	Pseudotsuga menziesii
Englemann spruce	Picea engelmannii
Incense cedar	Calocedrus decurrens
Grand fir	Abies grandis
Jack pine	Pinus banksiana
Loblolly pine	Pinus taeda
Lodgepole pine	Pinus contorta
Mountain hemlock	Tsuga mertensiana
Oregon white oak	Quercus garryana
Pacific madrone	Arbutus menziesii
Pacific silver fir	Abies amabilis
Ponderosa pine	Pinus ponderosa
Quaking aspen	Populus tremuloides
Red alder	Alnus rubra
Subalpine fir	Abies lasiocarpa
Western larch	Larix occidentalis
White fir	Abies concolor
SHRUBS	
Antelope bitterbrush	Purshia tridentata
Bearberry	Arctostaphylos uva-ursi
Big huckleberry	Vaccinium membranaceum
Big sagebrush	Artemisia tridentata
Chokecherry	Prunus virginiana
Common snowberry	Symphoricarpos albus
Curlleaf mountain-mahogany	Cercocarpus ledifolius
Currant	Ribes cereum
	Ribes viscosissimum
Deerbrush	Ceanothus integerrimus
Downy rabbitbrush	Chrysothamnus viscidiflorus puberulus
Golden chinkapin	Castanopsis chrysophylla
Greenleaf manzanita	Arctostaphylos patula
Grouse huckleberry	Vaccinium scoparium
Horsebrush	Tetradymia spp.
Mallow ninebark	Physocarpus malvaceus
Oceanspray	Holodiscus discolor
Oregon boxwood	Pachistima myrsinites
Oregon grape	Berberis aquifolium
Pacific rhododendron	Rhodondendron macrophyllum
Princes-pine	Chimaphila umbellata
Rabbitbrush	Chrysothamnus nauseosus
	Chrysothamnus viscidiflorus
Rabbitbrush goldenweed	Haplopappus bloomeri
Redstem ceanothus	Ceanothus sanguineus
Red elderberry	Sambucus racemosa
Rose	Rosa gymnocarpa
	Rosa woodsii
Salmonberry	Rubus spectabilis
Scouler willow	Salix scouleriana
Serviceberry	Amelanchier alnifolia
Snowbrush	Ceanothus velutinus
Spirea	Spiraea betulifolia
Vine maple	Acer circinatum
Western thimbleberry	Rubus parviflorus
Willow	Salix spp.

APPENDIX B (continued)

Common Name	Scientific Name
GRASSES AND SEDGES	
Bluebunch wheatgrass	Agropyron spicatum
Bottlebrush squirreltail	Sitanion hystrix
Cheatgrass	Bromus tectorum
Crested wheatgrass	Agropyron cristatum
Idaho fescue	Festuca idahoensis
Kentucky bluegrass	Poa pratensis
Mat muhly	Muhlenbergia richardsonis
Needle-and-thread	Stipa comata
Pinegrass	Calamagrostis rubescens
Prairie junegrass	Koeleria cristata
Sandberg bluegrass	Poa sandbergii
Slender wheatgrass	Agropyron trachycaulum
Subalpine (columbia) needlegrass	Stipa columbiana
Thurber needlegrass	Stipa thurberiana
Timber oatgrass	Danthonia intermedia
Elk sedge	Carex geyeri
Long-stolon sedge	Carex pensylvanica
Ross sedge	Carex rossii
FORBS	
Arrowleaf balsamroot	Balsamorhiza sagittata
Beargrass	Xerophyllum tenax
Bedstraw	Galium spp.
Bracken fern	Pteridium aquilinum pubescens
Broadleaf arnica	Arnica latifolia
Buffalo bur	Solanum rostratum
Corymbose pussytoes	Antennaria corymbosa
Death camas	Zigadenus paniculatus Zigadenus venenosus
Fireweed	Epilobium angustifolium
Heartleaf arnica	Arnica cordifolia
Indian paintbrush	Castilleja miniata Castilleja angustifolia
Indian potato	Trientalis latifolia
Iris	Iris spp.
Lambstongue groundsel	Senecio integerrimus
Licoriceroot	Ligusticum spp.
Lupine	Lupinus spp.
Pearly everlasting	Anaphalis margaritacea
Segolily	Calochortus spp.
Sheep sorrel	Rumex acetosella
Sidebells pyrola	Pyrola secunda
Stickseed	Hackelia spp.
Strawberry	Fragaria virginiana
Tarweed	Madia spp.
Tansy ragwort	Senecio jacobaea
Thistle	Cirsium spp.
Twinflower	Linnaea borealis
Western yarrow	Achillea millefolium
Wild carrot	Daucus carota
Wild onion	Allium spp.
Wyeth buckwheat	Eriogonum heracleoides